January 25, 2005

Mr. Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 440 Project Proposal for an Electronic Counter Sniper System

Dear Mr. One:

The enclosed document, *Proposal for an Electronic Counter Sniper System*, outlines AcousticShield's plan for the development and design of a system that would aid military and law enforcement personnel in quickly and accurately locating the origin of a gunshot.

Included in this proposal is a development schedule and a tentative budget that will be required for the successful completion of the project herein proposed. Also discussed is a possible implementation method of the system, as well as alternate implementation strategies.

AcousticShield is an ENSC440 project group, consisting of one fourth year and two fifth year students: Marko Gasic, Sandeep Brar and Ehsan Dallalzadeh. If you have any concerns or questions regarding this proposal, please contact me by email or by telephone at 604 340-8603.

Sincerely,

Marko Gasic

Marko Gasic,
President and CEO
AcousticShield Designs

Enclosure: *Proposal for an Electronic Counter Sniper System*

AcousticShield DESIGNS

Proposal for a

Electronic Counter Sniper System

Project Team: Marko Gasic
Sandeep Brar
Ehsan Dallalzadeh

Contact Person: Marko Gasic
acousticshield-ensc440@sfu.ca

Submitted to: Lakshman One
Michael H. Sjoerdsma
Steve Whitmore

School of Engineering Science
Simon Fraser University

Issued Date: January 25, 2005

EXECUTIVE SUMMARY

Asymmetric warfare is an unfamiliar term to most of us. For members of the armed forces and civil services however, asymmetric warfare has become the embodiment of a new generation of threats faced in peacekeeping and domestic anti-terrorism operations. No longer is the field of battle dominated by large cohesive armies exhibiting a balance of force, instead, mobile groups, or in many cases individuals, threaten large, mechanized, and usually much less mobile military formations. The inherent mobility and capability for easy concealment is what allows these individuals to inflict great damage on the much larger force.

As an example, consider a lone sniper in an urban environment. Such an individual has the ability to blend in and conceal among the civilian population, and strike at a much less mobile and very visible base of operations of a larger military formation. Due to the inherent difficulty in locating such a threat and responding in a timely manner, there exists no effective deterrent to prevent these attacks from taking place. Unfortunately, as was demonstrated in Washington D.C. in October of 2002, such threats are not limited to the military arena. Within a three week period, starting on October 2 2002, John Allan Muhammad and Lee Boyd Malvo killed 10 people and injured 4 others in a sniper shooting spree; police were powerless to prevent the attacks and relied on witness tips to attempt to identify the snipers (TIME Oct. 21 2002).

AcousticShield aims to develop an Electronic Counter Sniper (ECS) system that uses the acoustic signature of a gunshot to identify the precise location of the shooter immediately after the shot is taken. By denying the shooter anonymity and enabling quick and accurate localization, our system will enable military and law enforcement personnel to quickly and effectively locate and respond to such attacks. By making a response much more likely and effective, we believe that our system will act as a significant deterrent in prevent these types of attacks from occurring in the first place.

With this document, AcousticShield proposes and outlines a plan for development of the ECS system described above. Our group consists of 2 fifth year and one fourth year engineering science students with skills in systems integration and programming required to make this project a reality.

We propose a development timeline as well as a budget that will be required for the completion of the project by March 30 2005. We also indicate possible sources of funding for the estimated $2260.00 development cost.

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1. Introduction

During the Cold War people feared conflict between massive superpowers and giant armies. Now, the threat has changed, individual terrorists and urban warfare are the primary challenges our military and civil services face. In order to be effective, a small force or an individual must use mobility and camouflage to its advantage, to this end, sniper attacks have proven to be a highly effective means to harass and otherwise impede large military formations and bases.

AcousticShield aims to develop a system which uses an array of microphones to detect the acoustic signature of a gunshot, and by triangulation, locate the origin of the shot within seconds of the event. Since the speed of sound is relatively slow, the difference in time between which the sound of a gunshot is detected by individual microphones can be used to calculate with reasonable precision the location of the shooter.

Electronic Counter Sniper systems such as the one described are in existence today, however, due to their prohibitively high cost, they are available only to few elite military divisions, and are not considered standard equipment for regular army units or police forces. By developing an effective ECS system for under $2500, AcousticShield would give local police forces the tools necessary for providing added protection during special events and dealing with domestic terrorism as in the case of the Washington Sniper.

By augmenting the ECS system with a high resolution digital camera, it would be possible to take an image of a crime scene just as it happens, quite likely capturing a detailed image of the shooter, gun in hand. Such systems can be installed in high crime locations acting as a deterrent and a tool for police.

The intent of this document is to provide an overview of the ECS system, a possible design solution as well as alternate solution possibilities. We also present a development schedule, budget and possible sources of funding. We believe that skills and experience of the AcousticShield group will allow us to successfully build a prototype of this system within the given schedule and budget constraints.

2. System Overview

The Electronic Counter Sniper system, a product of AcousticShield Designs is an acoustic sniper localization system. ECS system employs omni directional microphones arranged in a tetrahedral geometric configuration, state of the art DSP hardware and advanced localization algorithms to identify the source of sniper fire in real-time. **Error! Reference source not found.** below illustrates the conceptual design of the system.

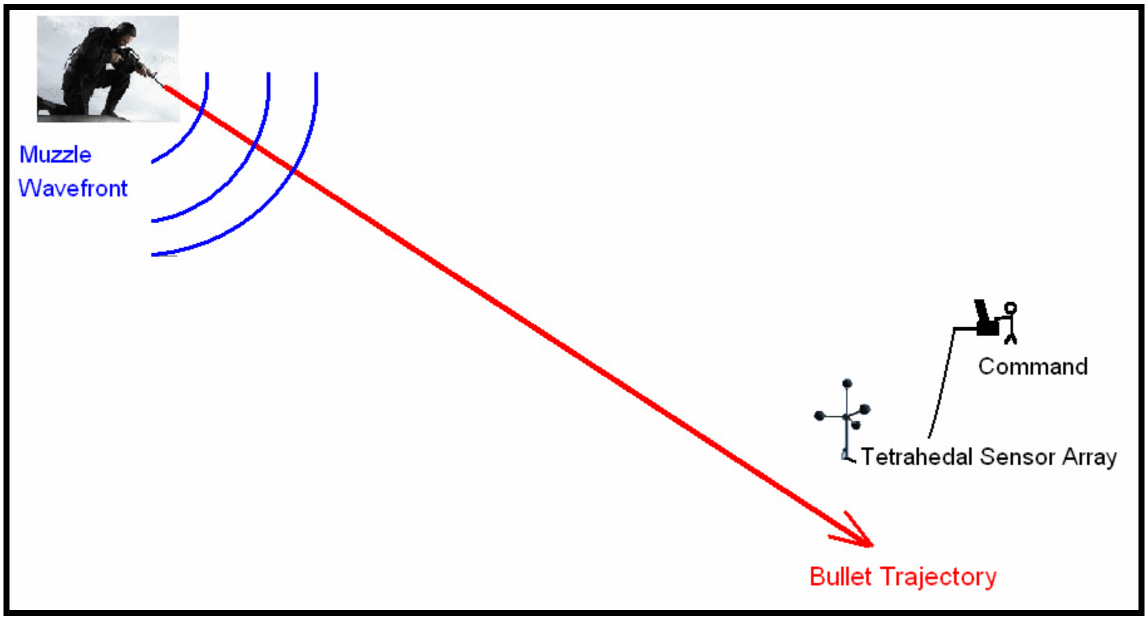

Figure 1: Sniper localization system concept

The system consists of three functional components as follows:

- Distributed sensor array with omni directional microphones
- Digital Signal Processor for data acquisition and real time processing
- 3D visualization and output interface

In essence, the system is a passive device that calculates the origin of a bullet based on the time delay between the arrival of an acoustic wave front at several microphones. This system is intended to be portable and easily deployable on a battle field or a forward base of operations.

3. POSSIBLE DESIGN SOLUTIONS

There exist a number of solutions to the problem of locating the origin of a sniper shot. Each of the possible design concepts presented in this section have certain advantages as well as design challenges. The core of the system, a real-time Digital Signal Processing (DSP) unit, is common to all solutions; it is the system input that varies.

3.1 Muzzle Flash Detection

When a bullet is fired from a barrel of a gun, the resulting explosion is directed through the muzzle towards the opening. This results in the emission of light both in the visible and IR spectrum. A CCD camera could be used to scan the surrounding field of vision and a DSP system would be used to identify the flash. This system is capable of accurately detecting the location of the shooter, and since light travels much faster than the bullet, the location of the shooter could be determined before the bullet reaches its destination. However, the requirement for several high resolution CCD cameras and possibly an infrared camera system would make such a system much more expensive than the $2500 target cost. In addition, reflections from windows and variability in ambient lighting would result in a high false positive rate.

3.2 Sniper Optics Reflection

Assuming the shooter uses some sort of targeting optics, an IR laser system could be set up to sweep the field of vision. Once the laser beam strikes the optics of the sniper, it would be reflected towards the origin of the laser (we are assuming that the sniper optics will be perpendicular to the origin of the system if the sniper is aimed towards a location where the ECS is deployed) The major advantage of the laser sweep system is that a sniper could be located before he ever takes the shot. However, as in the muzzle flash concept, the price would be above the given range, and reflections from any glass surface perpendicular to the origin of the laser would result in false positives.

3.3 Acoustic Signature Detection

Since sound travels at approximately 330m/s in air, the time delay between the wave front reaching microphones separated in space could be used to triangulate the origin of the sound. Unlike the previous systems described, the system would provide a location only after the bullet has reached its target. We don't believe this to be a serious disadvantage because the additional 1-2 seconds provided by the light detection systems would not be enough time for any kind of a response action. Since regular microphones could be used for signal acquisition, the overall system cost could be significantly reduced. In addition, since each weapon creates a distinct acoustic signature, DSP techniques can be used to differentiate between actual gunshots and other loud sounds, significantly reducing false positives. Effects of echo can also be canceled using DSP processing techniques.

4. PROPOSED DESIGN SOLUTION

At the instant a bullet leaves the barrel of a weapon, an acoustic wave front is generated and expands radially in 3 dimensions from the location of the shooter at the speed of sound. This is of course what we perceive as the sound of a gunshot. Using same principles that humans use to locate the origin of a sound, AcousticShield Designs ECS system uses a distributed network of omni-directional microphones to detect the sound of the bullet and calculate the location of its origin. For the proposed system solution overview, refer to Figure 2.

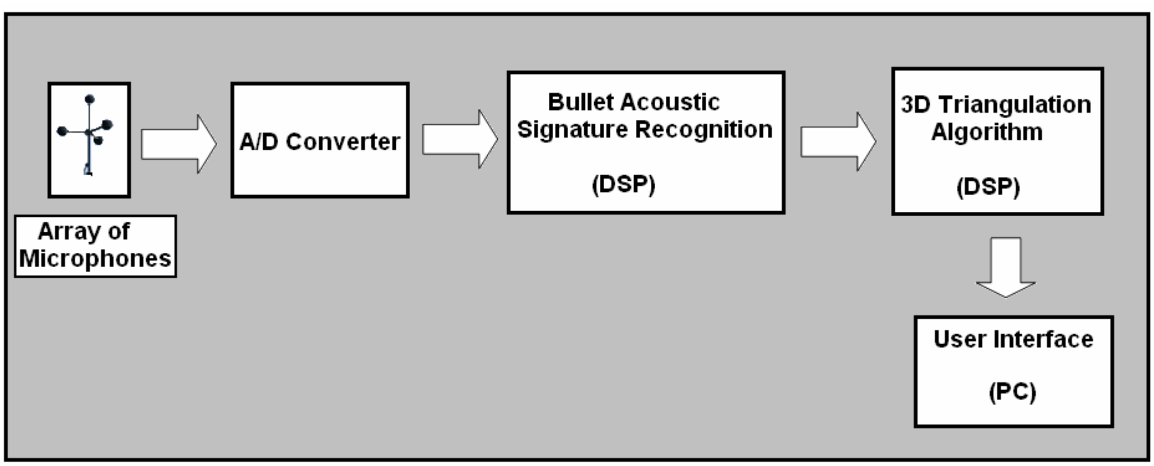

Figure 2: Proposed System Solution Overview

By detecting the time delay between arrivals of the acoustic waves at four microphones, arranged in a tetrahedral pattern, a DSP processor is able to quickly calculate the origin of the sound, outputting the direction in polar co-ordinates or as a Cartesian direction vector. The reason for a tetrahedral pattern lies in the fact that for geometric triangulation, n+1 points are required to determine a location in an n dimensional space, so for three dimensional space, four sensors are the minimum requirement. The tetrahedral pattern is a natural distribution that results in 4 equally spaced sensors in three dimensions.

The advantage of using a DSP based system is that it responds in real time, allowing for an almost zero lag output. In addition, the algorithms available on modern DSP processors allow for easy processing of input, easy echo cancellation and waveform identification. This means that once the basic system is implemented, it can easily be modified so that it tolerates operation in a complex environment where echo and other noise would pose a problem to similar systems. In addition, since each type of weapon generates a distinct sound profile, the system could be trained not to respond to a particular sound profile, such as the sound generated by discharge of weapons used by friendly forces.

Once the processor has calculated and output the co-ordinates of shot origin, a PC based or embedded application reproduces the output in a visual format so that the system operator can take appropriate action. In addition, these co-ordinates could be used to position a camera to capture an image of the location where the shot came from. Due to the limited time frame, this additional feature will not be implemented by AcousticShield at this time.

5. SOURCES OF INFORMATION

To implement our project, we need to access a variety of sources of information on the DSP Evaluation Modules, microphones, Matlab, and mathematical concepts related to triangulation. First, we need to get familiarized with the boards that we are using; both the main DSP platform as well as the daughter board which provides for analog to digital signal conversion. A large information database as well as a technical knowledge center is provided by Texas Instrument on their website at www.ti.com. Also we need information on microphones that are available; we will use the internet, academic books and journals and colleagues familiar with audio signal processing to determine which microphones to incorporate into our project. Moreover, we need to know more about the tools that MATLAB provides us with such as the Signal Processing Toolbox, Real-time Workshop and Embedded Target for TIC6000 EVM. Finally, we need to get more information on the sniper characteristics with respect to their frequencies and maximum ranges. We get that information from the web mostly as well. Of course, in all of the above parts, we will contact our TAs and consider their input and knowledge as a valuable source of information.

6. BUDGET AND FUNDING

6.1 Budget

A tentative budget for AcousticShield's ECS system is outlined in Table 1. The budget is based on all of the components we expect to use in the proposed design. Estimated cost doesn't include duties that may apply when ordering the parts from USA. Currency fluctuations were not considered because risk of Canadian dollar loosing ground against the America dollar in the period of 2 weeks is considered to be minimal, at best.

Table 1: Tentative Budget

System Module	Estimated Cost	Source
Development Board *TMS 320C6X EVM*	$2000	Texas Instruments
A/D Converter *Multi-Converter-EVM - 0309*	$100	Texas Instruments
Microphone *Omni Directional*	$65	Digi-Key Catalog
Tetrahedral Camera Stand	$65	Future Shop
Cables and Connectors	$30	Digi-Key Catalog
Total Cost	$2260	

6.2 Funding

The development of sniper localization prototype requires a significant amount of capital. Even though DSP platforms are usually only few hundred dollars, evaluation modules used for prototype development can increase the cost of the project. This is the main reason why the cost of our project is in thousands rather than hundreds of dollars.

The major resource of funding for engineering science projects in the past has been ESSEF grant. Application for ESSEF grant is already under way and will be submitted with in a week. We estimate with high probability that we would be able to secure between one hundred dollars to two hundred dollars from ESSEF grant.

Under the economical environment we live in, finding funding for any project is a difficult task at best. Keeping this in mind we are looking for ways to reduce the cost of the project. Most expensive hardware for the project is the DSP EVM board and we believe that we will be able to loan the board from the SFU Engineering Science department.

Any expenses that exceed the available funding will be covered by team members' personal funds.

7. SCHEDULE

Figure 3 shows a Gantt chart of expected time to be spent in achieving different milestones. Milestone "Localization in Noisy Environment" will be attempted only if we are more than one week head of schedule by March 6th.

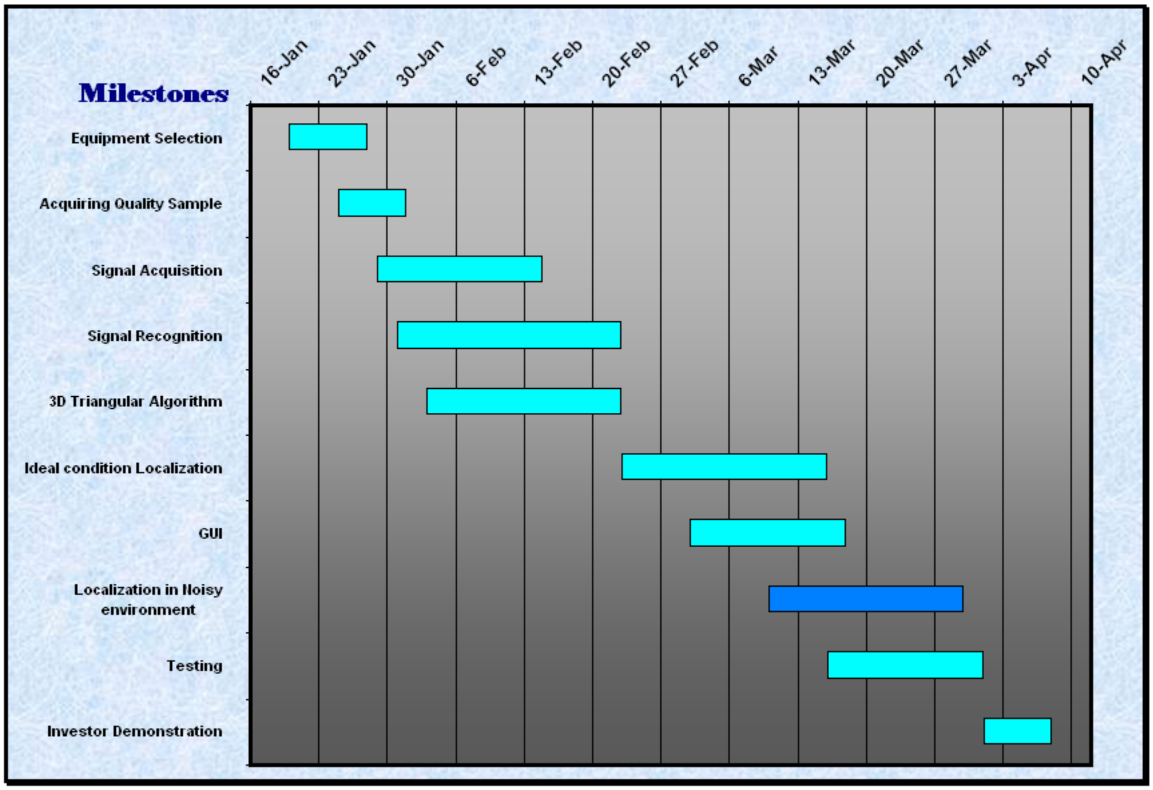

Figure 3: Project Schedule

8. TEAM ORGANIZATION

The members of AcousticShield Designs have different areas of expertise that are applicable to the project. Talented group of individuals, Marko Gasic, Sandeep Brar, and Ehsan Dallalzadeh bring skills from Systems, Electronic and Computers engineering respectively. Our different ways of looking at a problem will be vital in helping the group in finding solutions, to obstacles that may arise in development of our system, efficiently.

While recognizing the complexity of the project we have decided to split the project into subcomponents and assign individuals the responsibility of a particular subcomponent. One of the benefits of *"clearly assigning task responsibilities" (Shahir Popatia, 2000, 1)* is time efficiency, which we feel outweighs the risk of having problems during integration phase of the project. We have scheduled weekly technical meetings, aside from a mandatory meeting required by ENSC 440, to ensure we develop subcomponents that are compatible with one other. Furthermore in our schedule we have reserved about a month for integration and testing.

In an initial meeting on January 20, 2005 a team objective was outlined, in which we clarified our expectations for the project and expectations from one another. We agreed upon ways of communication [1] that is acceptable with the entire team. This meeting was vital in getting our group dynamics started on the right foot. It was also noted and agreed upon that a hierarchical system would conflict with the dynamics of the group, thus leadership role would be equally shared. We also assigned subcomponents of the system according to member interests and strengths. Although more emphasis was given on interest, each group member gave a supportive argument on a part they preferred, in order insure they had the capability to accomplish the task with high quality.

To increase efficiency and effectiveness of our team we will promote the development of characteristics described below:

> *"Team members frequently interact;*
> *Team members share the decision making power (although often, but not always, a tacit team leader exists);*
> *Tasks are equitably divided;*
> *The team shares the responsibility for both their mistakes and their successes;*
> *The free expression of opinions, conflicting perspectives, and constructive criticism is always encouraged" (Steve Whitmore & Susan Stevenson, 1999, 21).*

With these fundamental in mind we believe that we will not only be able to finish the project, we may even become closer friends.

9. Company Profile

The members of Acoustic shield board have different backgrounds and academic experiences. This, besides their enthusiasm and motivation in the project, gives us the confidence that we will successfully complete the project.

Marko Gasic, President & Chief Executive Officer

Marko Gasic was appointed president and chief executive officer of AcousticShield Designs in January 2005.

Marko Gasic is a fifth year engineering science student in the Systems Option, at Simon Fraser University. Marko completed his Co-op program at Perceptronix

[1] Communication: The art and technique of using words effectively to impart information or ideas.

Medical Inc., where among other tasks he was responsible for implementing a voice recognition system on a medical imaging device used to allow doctors hands free operation. As co-founder of SARAN ElectronicWorks Ltd., Marko has gained valuable business and entrepreneurial experience.

Sandeep Brar, Strategic Development Vice President

Sandeep Brar was appointed strategic development vice president of AcousticShield Designs in January 2005.

Sandeep Brar is a fifth year Engineering Science Student in the Electronics Option. Prior to this appointment, Brar was with Rockwell Automation system's as a test engineer. From a year along Co-op, he not only brings valuable skill of product development cycle and quality insurance, he is also knowledgeable in advanced control systems. Before joining Rockwell he was involved in advanced research in autonomous helicopter as part of Arial Robotic Group at Simon Fraser University.

Ehsan Dallalzadeh, Chief Operating Officer

Ehsan Dallalzadeh was appointed chief operating officer of AcousticShield Designs in January 2005.

Ehsan Dallalzadeh has completed four years at Simon Fraser University School of Engineering Science, Computer Engineering option. Having taken all the lower year courses has prepared him to go about working on this project. Besides all the material that he has learned previously, by doing a research work experience, he has learnt how to research and learn new things on his own. Also, in the mean time, he is the president of a learning academy that he and his partner own. Moreover, joined with another partner who is overseas, he is trying to finish and market their own new digital thermostat starting from the Middle East. The latter two activities have given him lots of management skills besides other useful skills. He is also a member of a music band composed of a couple of UBC students. In his spare time, he does long-distance road cycling and recently started his training in a martial art.

10. CONCLUSION

Developing an acoustic based Electronic Counter Sniper system priced at below $5000 would give law enforcement agencies and nearly every military unit access to this valuable law enforcement and threat deterrent tool. At AcousticShield Designs, we feel confident in our ability to develop a prototype of the system described in this document. By employing DSP technology in our design, reliable and modular system operation can be achieved. Future design augmentations and upgrades, such as installation of a camera system, echo cancellation and waveform recognition can be integrated onto the basic system due to multifunctional capabilities of the DSP platform.

By sourcing a large portion of system components (DSP Platform) from SFU Engineering Science department, we will be able to significantly reduce our cash requirements. We will seek additional funding from ESSEF and other sources, the balance will be provided by AcousticShield member contributions. Project timeline presented in this document will allow for development of the core system, with the possibility of further expanding functionality and improving performance at a later time.

The knowledge and experience derived by learning system integration and DSP platform implementation will be an invaluable addition to the engineering skill set of our team members. Technologies used in AcousticShield's ECS system, are modern and practical, they are directly transferable to industry and our team members will certainly benefit from knowledge acquired during the course of this project.

11. REFERENCES

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